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Long - term influence of solar activity and CMEs with cosmic ray intensity variations

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Abstract

In the present study, we investigate the relationship between coronal mass ejection (CMEs), Sunspot number (Rz), Geomagnetic index (Ap) and Cosmic ray intensity (CRI) variations on long-term basis. In this work, we have studied the effects of CMEs rates on cosmic rays and sunspot number for the solar cycle 22 to ascending phase of recent solar cycle 24, year 1986 to September 2014. We have used three different neutron monitors data located at Beijing, Moscow and Oulu. From the analysis, we observed a good relationship between occurrence rate of CMEs, cosmic ray intensity and sunspot number (Rz) modulation and it has been found that the anti-correlation between CRI (Beijing) with geomagnetic index Ap is strong during the period of 1986 to 2014.

Key words: Cosmic rays, geomagnetic index, SSNs, and CMEs

Introduction

Long-term Cosmic ray intensity variation and its association with solar activity as well as geomagnetic activity were studied by number of workers time to time[15,20]. Solar terrestrial studies in relation to Cosmic ray modulation support us to explain the 11/22 year variation of Galactic cosmic rays. Various solar output occur on the surface of the Sun, in turn propagate their energy through solar wind and interplanetary magnetic field to long distance in heliosphere. Consequently affect the high energy Cosmic ray particles as well as produce geomagnetic disturbances. Galactic cosmic ray in the energy range from several hundred Mev to few Gev are subjected to heliospheric modulation because solar output and its variation affect their intensity and spectrum during 11 year solar activity cycle. It is also known that cosmic ray intensity variation show inverse correlation with sunspot number and geomagnetic index do not coincide with minimum / maximum of cosmic ray intensity. Cosmic rays are one of the measure radiations in interplanetary medium, which is used as a tool to study the various activities in interplanetary medium as well as near the earth environment. Cosmic rays are being continuously detected since 1953 using the various ground based detectors. Time variation of cosmic ray intensity has been studies by a number of cosmic ray researchers Tiwari *et.al.*,[19]. Relationship of cosmic ray intensity with solar activity and geomagnetic activity has been studied since last three decades by a number of cosmic rays scientists[8,12,13,18]. However, long- term modulations studies have still its relevance in recent days[5].

Coronal mass ejections have been recognized as the most energetic phenomenon in the heliosphere driving their energy from the stressed magnetic fields on the sun. CMEs are associated with erupting prominences throughout the solar activity cycle and may act as a solar activity index. The consequences of CMEs in the interplanetary medium have been discussed Gopalswamy *et.al.*[6]. CMEs appear to surround the occulting disc of the observing white light coronagraph in the sky plane projection and expands rapidly are known as halo CMEs which may be backside or front side.

The variation in galactic cosmic ray (GCR) intensity due to solar activity has been known since almost half century ago Forbush 1954. Many mechanisms have proposed to explain the decreasing GCR flux in inner heliosphere Belov[2]. The basis of GCR modulation theory was established by Parker[14]. CMEs are large scale phenomena that change the configuration of the IMF and clearly modulate the cosmic ray intensity on short term basis. Therefore it is natural that CMEs may also play a vital role in cosmic ray modulation on long- term basis. CMEs are contributing to the propagating barriers GMIRs that are believed to be the cause of long-term cosmic ray modulation Shrivastava *et. al*.[16]. Nevertheless major geomagnetic storms are found to be mainly caused by CMEs [7,21]. Numerous severe storms occur during the maximum phase of CMEs[6].

Coronal mass ejections are the coronal feature of the sun and can carry as much as 10 billion tons of solar material and may produce geomagnetic storms, interplanetary shocks and Forbush decreases in cosmic ray intensity if they hit earth's magnetosphere. Coronal mass ejections which are earth directed celled halo events because of the way they in chronograph images. As expanding cloud of an earth directed CME looms larger and larger it appear to envelop the sun, forming a halo around our sun. In this study only halo and partial halo CMEs has been taken into consideration. Several investigators with solar flares and coronal mass ejections have studied the asymmetric cosmic ray intensity decreases (Fds) events. Some investigator says that their is strong correlation between asymmetric cosmic ray intensity decreases (Fds) and solar flares[10]. also noted that there is no direct association between the amplitude of Forbush decrease and the location on the sun of instigating flare. Other investigators say[7,4,9,3,1] that asymmetric cosmic ray intensity decreases (Fds) are produced by coronal mass ejections not solar flare. Gupta *et. al*.[9] have suggested that the two step that asymmetric cosmic ray intensity decreases (Fds) are caused by the combination of a shock and eject (an interplanetary signature of coronal mass ejection).

Data and Method of Analysis:

In present study, we have used the data received for the three different neutron monitors located at Oulu (Longitude 25.5 E, Latitude 65.02 N and cut off rigidity 0.81 GV);

Moscow (Longitude 37.3 E, Latitude 55.4 N and cut off rigidity 2.39 GV); Beijing (Longitude 116.2 E, Latitude 40.0 N and cut off rigidity 9.56 GV). Oulu and Moscow station are located at middle/high latitude having low cut off rigidity, while Beijing are located at low latitude having high cut off rigidity, neutron monitor stations have been obtained for the website www.cosmic ray neutron monitor data and NGDC/WDC, STP, Boulder Cosmic rays. We have also used coronal mass ejection CMEs, data from solar heliosphe-ricobservatory (SOHO) and large angle and spectrometric coronagraph (LASCO) CMEs catalogue (http://cdaw.gsfc.hass.gov/CME_list). We have also used Sunspot number (Rz) and geomagnetic index (Ap) from solar geophy-sical data books and data have been taken from the website www.omni web gsfc.noaa.gov. similarly, Sunspot number (Rz) have been downloaded from ngdc.noaa.gev. We have used all the halo CMEs data observed by SOHO/LASCO from 1996 to 2013 taken from the SOHO/LASCO halo CMEs and partial halo CMEs catalog.

Results and Discussion

The sun and its output inform of various interplanetary features such as solar plasma, interplanetary magnetic field is related to the disturbance in earth magnetic field. Using the yearly mean value of sunspot number (Rz), CRI (Oulu, Moscow and Beijing) neutron monitors data and geomagnetic index (Ap) ,are calculated for the solar cycle 22 to ascending phase of recent solar cycle 24, which is occurred during 1986 to September 2014. We have observed CMEs (Halo and Partial Halo) for the periods of solar cycle 23 and ascending phase of recent solar cycle 24, which is occurred during 1986 to 2013, based on 588 number of CMEs (Halo) events and 1021 number of CMEs (Partial Halo) events. In figure 1, we show the frequency distribution of the yearly number of CMEs (Halo and Partial Halo) event with annual average of sunspot number (Rz) for the solar cycle 22 to ascending phase of recent solar cycle 24, which is occurred during 1986 to September 2014. Thus, we concluded that, CMEs (Halo and Partial Halo) event are highly correlated with SSNs, figure 1, shows the maximum number of CMEs (Halo and Partial Halo) events are observed in years 2001 and 2012, (120, 63 and 151, 84) of solar cycle 23 and ascending phase of recent solar cycle 24, and minimum number of CMEs (Halo and Partial Halo) events are observed in years 1996, 2008 and 2009. Figure 1 shows the correlation between annual mean values of sunspot number Rz and CMEs (Halo and partial Halo) for the periods of 1996 to 2013. Scatter of points show positive correlation between sunspot number Rz and CMEs (Halo and partial Halo). For this analysis we have used the yearly mean value of CRI (Beijing) neutron monitors data to derive the long-term relationship with geomagnetic index (Ap) for the period 1986 to September 2014,which covers the solar cycle 22,23 and ascending phase of 24 solar cycle. Figure 2 shows the yearly association of cosmic ray intensity (CRI) for Beijing with Ap index from 1986 to September 2014, which clearly depicts anti-correlation between CRI with Ap index. Which clearly depicts anti-correlation between CRI with Ap index. Figure 3 shows cross plot between yearly mean value of CRI (Oulu and Moscow) with yearly number of CMEs (Halo and Partial Halo) events for the solar cycle 23 to ascending phase of recent solar cycle 24, which is occurred

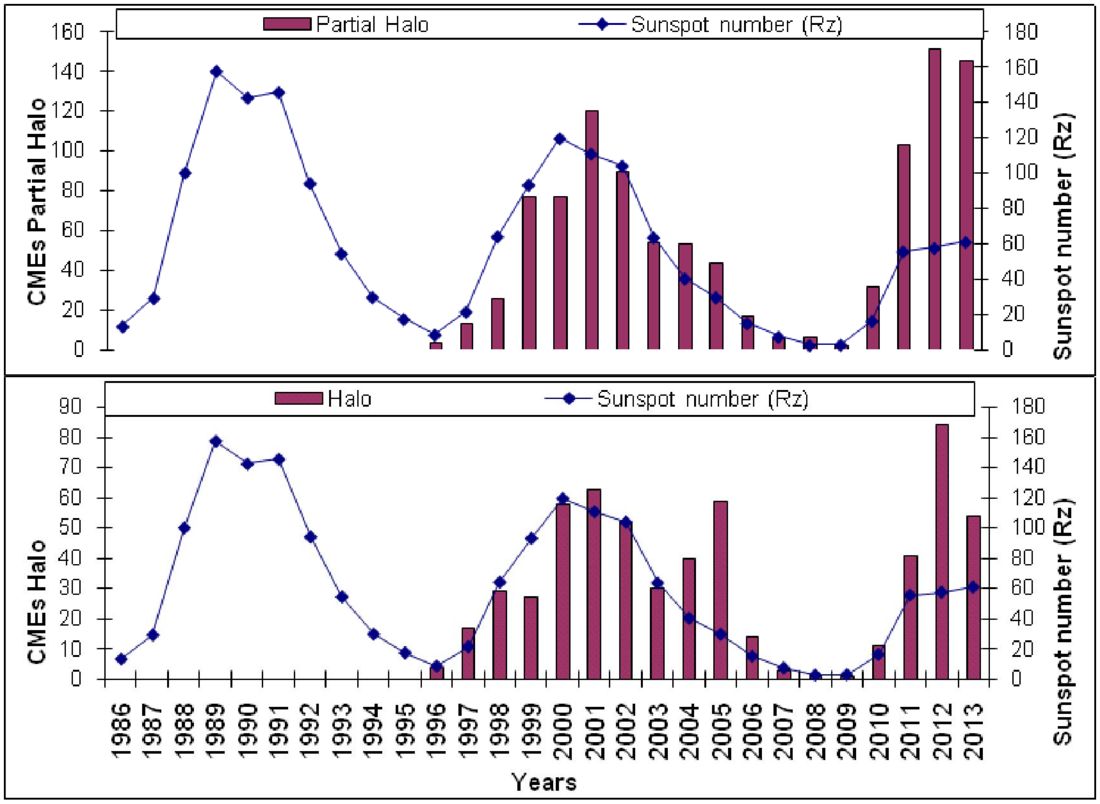

Figure 1 : Plot shows the total annual number of CMEs (Halo and Partial Halo) event time with annual mean values of Sunspot number (Rz) for the periods of 1986 to 2013.

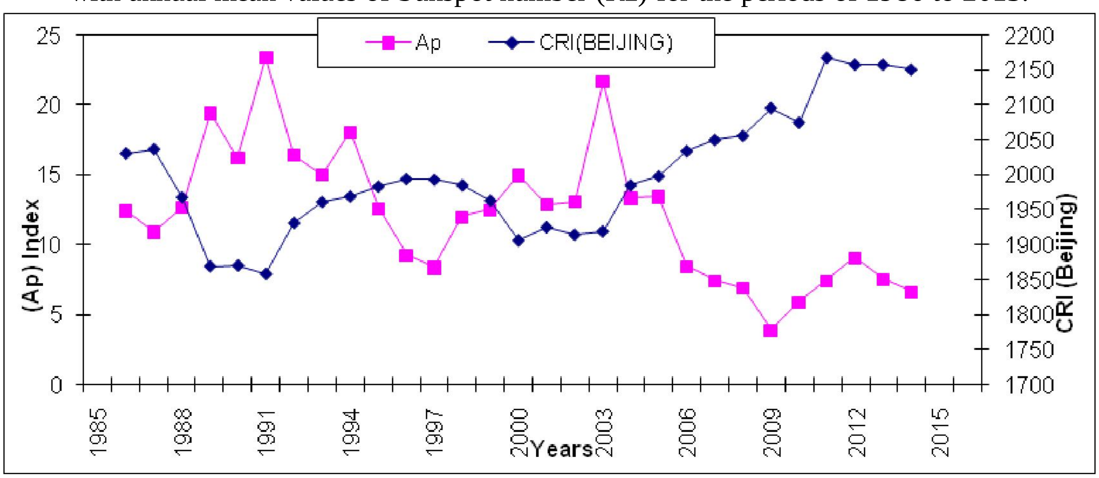

Figure 2: Shows the annual mean value of geomagnetic index (Ap) with cosmic ray intensity (Beijing) during the solar cycle 22 to ascending phase of recent solar cycle 24 (1986 to Sepetember 2014).

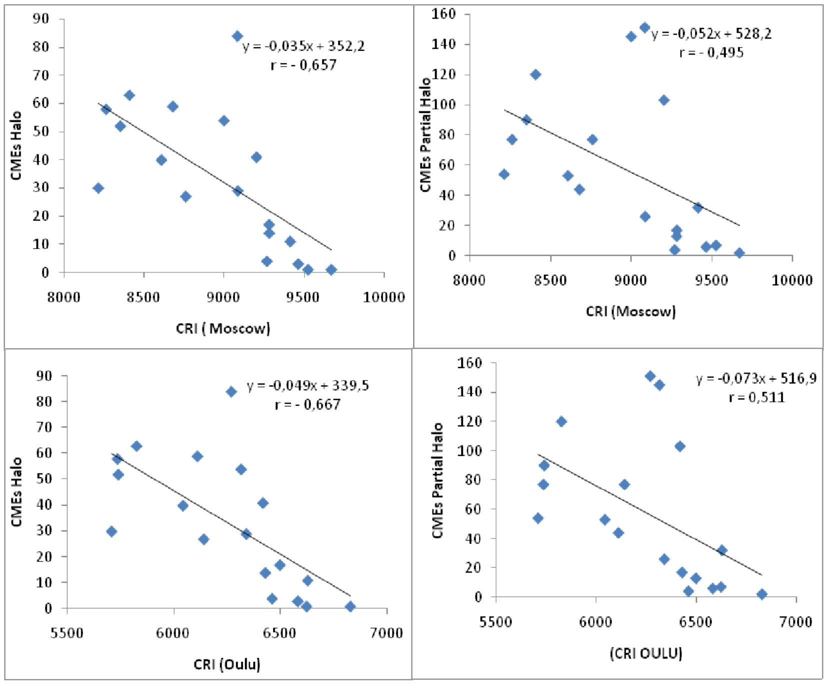

Figure 3 : Shows cross plate between yearly event of CMEs (Halo and Partial Halo) during event time with yearly mean value of Cosmic ray intensity (Oulu, Moscow) during period for the interval (1996 to 2013).

during 1996 to 2013. Correlation coefficient between CRI for (Oulu and Moscow) with CMEs (Halo and Partial Halo) events are found -0.667, -0.511,-0.657 and -0.496 respectively. Thus, we concluded that CRI for (Oulu and Moscow) is highly negative correlated with CMEs Halo events and CRI for (Oulu and Moscow) is good negative correlated with CMEs Halo events. Recently coronal mass ejections are found to be one of the main factor in short–term cosmic rays intensity variations[11,17].

Conclusions

- CMEs (halo and partial halo) events are highly correlated with sunspot number (Rz). It is maximum occurred during maximum activities years.
- Cosmic ray intensity (CRI) with geomagnetic index (Ap) are anti-correlated.
- Annual of CMEs (Halo and Partial Halo) events are minimum events during the ascending phase of solar cycle 24 as compare to another, ascending phase of solar cycle 23. Hence solar cycle 24, will be very weak compare to solar cycle 23.
- Annual of CMEs (Halo and Partial Halo) events with CRI (Oulu and Moscow) is negative correlated.

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website www.cosmic ray neutron monitor data and NGDC/WDC, STP, Boulder Cosmic rays. We have also used coronal mass ejection CMEs, data from solar heliosphericobservatory (SOHO) and large angle and spectrometric coronagraph (LASCO) CMEs catalogue (http://cdaw.gsfc.hass.gov/CME_list).

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